COST AND PERFORMANCE REPORT

Multi-Phase Extraction at the Tinkham's Garage Superfund Site
Londonderry, New Hampshire

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EPA
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A full-scale Dual Vacuum Extraction (DVE) system was designed and constructed at the Tinkham's Garage Superfund site to simultaneously draw down the water table and remediate approximately 9,000 cubic yards (cy) of VOC-contaminated soil by vapor extraction. Soil cleanup goals were achieved within ten months of operation. Groundwater cleanup goals were not met in this time, and groundwater is currently being addressed through a pump-and-treat remedy. Remediation efforts were lead by the potentially responsible parties (PRPs) with Terra Vac, Inc. performing the design and operation of the DVE system and U.S. EPA Region 1 providing regulatory oversight.

Summary Information

The Tinkham's Garage site includes 375 acres of residential and undeveloped land in Londonderry, NH, situated in the southern portion of the state. Land use at the site includes a 400 person residential condominium complex, single-family homes, and undeveloped wooded areas, open fields, and wetlands. The Tinkham Realty Company and Tinkham's Garage, a large steel building, are located in the northeastern section of the site.

EPA site investigations in 1981 revealed onsite soil and groundwater contaminated with VOCs, including PCE, TCE, and BTEX compounds. These contaminants were determined to be the result of unauthorized surface discharges of liquids and sludge in 1978 and 1979. Three source areas were delineated. Two source areas included a soil pile behind the condominium complex and soil overlying the condominium complex leachfield. The third source area, of approximately one acre in size, is located behind Tinkham's Garage ("Garage Area" or "1 ppm Area") and is the focus of the remedial action summarized in this case study.

The nature and extent of soil and groundwater contamination at the site has been characterized by several site investigations. These investigations included a remedial investigation in January, 1985, a feasibility study in July, 1986, a pre-design study in July, 1988, and a vapor extraction pilot test in July, 1988. These investigations found total VOCs as high as 652 ppm in soil and 42 ppm in groundwater located in shallow, overburden and bedrock aquifers. A site characterization summary is provided in Table 1 and a chronology of events in Table 2.

Table 1. Site Characterization Summary for Tinkham's Garage

Parameter	Characteristics
Geologic Setting of Source Area	• Overburden consisting of inorganic and organic silty clay and sand grading to fine and medium-grained sand with depth • Weathered metamorphic bedrock at approximately 14 feet bgs
Depth to Groundwater	5 to 6 feet bgs
Aquifer Parameters	Approximate Values: • K = 1 ft/d (overburden silts and clays) • K = 10 ft/d (overburden sands) • T = 900 gpd/ft (bedrock)
Constituents of Concern	Tetrachloroethene (PCE) and Trichloroethene (TCE)
Pre-Remediation Concentrations	Total VOCs in Soil: 652 ppm, maximum Total VOCs in Groundwater: 42 ppm, maximum
Volume of Contaminated Media	Soil: 9,000 cubic yards

Unit Notes: bgs = below ground surface; ft/d = feet per day; gpd/ft = gallons per day per foot; ppm = parts per million

Source: U.S. EPA (1989); Terra Vac (1996), HSI GeoTrans (1999)

Table 2.Timeline of Remedial Activities at Tinkham's Garage

Activity	Period of Performance/ Date of Completion
Remedial Investigation	January 1985
Feasibility Study	July 1986
Record of Decision (ROD) Signed	September 30, 1986
Vapor Extraction Pilot Study	December 1987 - January 1988
Pre-Design Study	July 1988
ROD Amended to Include Dual Vacuum Extraction (DVE)	March 1989
Discharge Strategies Evaluated	August 1990 - July 1992
Construction of Sewer Line Between Derry and Londonderry Begins	August 1993
DVE Work Plan Submitted	February 1994
Excavation and Restoration of Condominium Areas	March - April 1994
DVE Construction and Drilling at Tinkham's Garage Begins	May 1994
Issuance and Approval of Industrial Discharge Permit to Town of Derry POTW	August - October 1994
DVE System Operation Begins	November 22, 1994
Closure Sampling Plan Submitted	July 1995
DVE System Operation Terminated	September 29, 1995
Final Soil Sampling Conducted	October 1995
Final Site Inspection	October 25, 1995
Demobilization of DVE System	November 1995
Construction of Groundwater System for Management of Migration (MOM)	November - December 1995
MOM System Operation	January 1996 - Present

Source: After Terra Vac (1996).

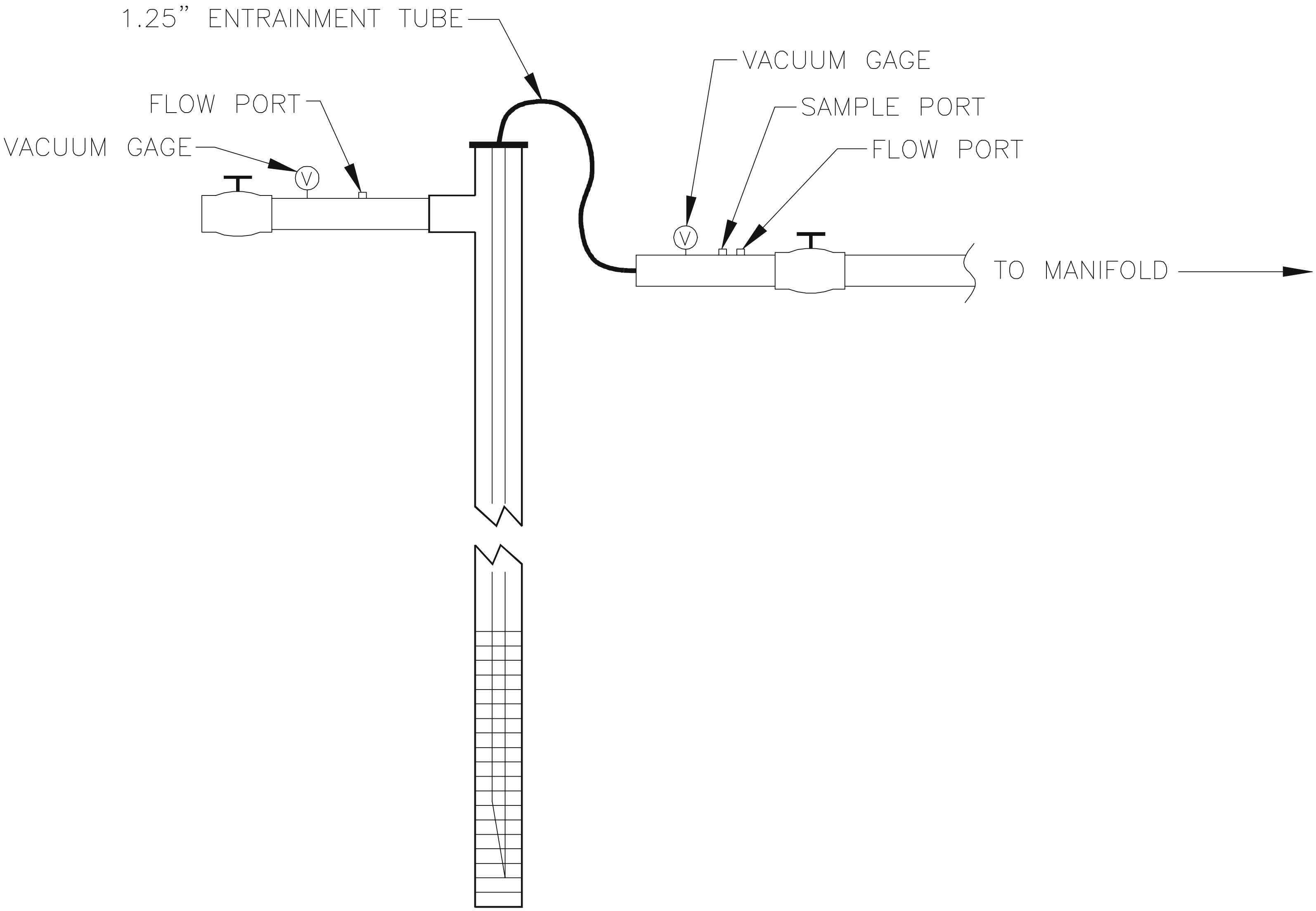
The Superfund Record of Decision (ROD) issued in September, 1986 identified the selected remedy as excavation of approximately 10,800 cy of contaminated soil with onsite treatment by either thermal aeration, composting, or soil washing. The local wetlands impacted by excavation and groundwater were also to be remediated. As a result of the pre-design and pilot studies, the ROD was amended in March, 1989 to require the treatment of approximately 9,000 cy of onsite soil by DVE. DVE was selected to target VOCs in soil beneath the saturated zone. This would be achieved by simultaneously lowering the shallow water table and exposing formerly saturated soil to air flow. The rationale for using DVE for soil remediation was based on its ability to dewater the shallow aquifer and expose the contaminated soil to SVE. Both the original and amended RODs set cleanup goals at 1 ppm total VOCs for soil and 5 ppb each for PCE and TCE in groundwater. The ROD also called for long-term management of migration (MOM) through groundwater pumping of deep bedrock wells and a shallow recovery system until cleanup standards for PCE and TCE are obtained. Pumped groundwater was to be discharged to the Derry, New Hampshire publicly-owned treatment works (POTW).

Technology Description and System Design

Consolidation of all VOC impacted soil was determined to be the most cost-effective means for remediation. Approximately 3,000 cy of contaminated soil from three areas near the condominium complex was excavated and hauled to the Garage Area. The excavated soil was then spread within the garage 1 ppm Area and compacted in place. The volume of soil requiring remediation, including the native and excavated soil, totaled 9,000 cy.

The DVE system consisted of 33 DVE wells divided into 25 shallow DVE wells, screened in the overburden, and 8 deep DVE wells, screened in the upper bedrock and overburden. Five existing pilot test wells were left in place and used for vapor extraction. The wells were distributed over three manifold lines to provide the greatest coverage over the area of contamination. The DVE well configuration used was the two-pump system, however, a central pump station consisting of two, 7.5-hp jet pumps was used for groundwater extraction instead of submersible pumps at each well. The jet pump system was capable of a flow of 1.5 gpm per well and was regulated by a valve at each wellhead. A schematic of a typical DVE well and wellhead manifold is provided in Figure 1. Wellhead vacuum and vapor extraction was achieved by two, parallel operating portable vacuum extraction units. Each unit included a 40-hp positive displacement blower capable of extracting 500 scfm at a vacuum of 12 inches

Figure 1. Schematic of DVE Well and Manifold (Terra Vac, 1996)



of mercury (in Hg). Vapor treatment was achieved by four 1,000 pound canisters of activated carbon. Two of these four canisters operated in series with the remaining two serving as secondary units. Two additional canisters were kept onsite to provide immediate replacements, if necessary. Initially, groundwater treatment by air stripping was necessary to meet the Derry POTW pre-treatment standards. Air stripper off-gas treatment was provided using vapor phase carbon. Figure 2 provides a process flow diagram of the DVE system.

Technology Performance

Operation of the DVE system lasted 311 days from November 22, 1994 to September 29, 1995. During system operation, operational data were routinely collected to serve as a means of monitoring system performance. A summary of the performance data from the DVE system is provided in Table 3.

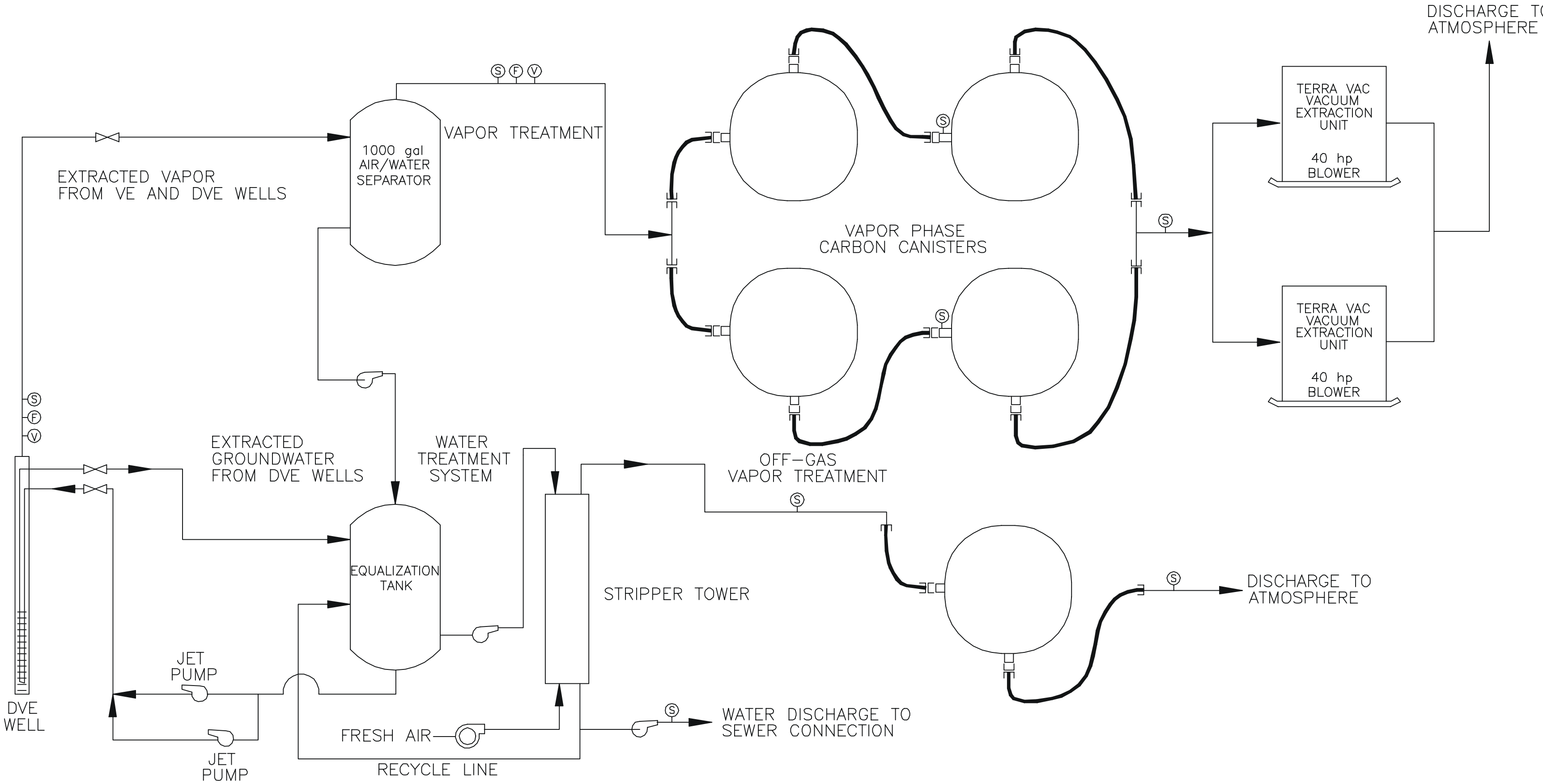
Table 3. Summary of DVE system performance data

Parameter	Value
DVE System Operation	311 days
SVE Vacuum at Blower	5 in Hg (≈68 in WC), average operational value
SVE Flow Rate	500 scfm, average operational value
Cumulative Volume of Extracted Groundwater	1,116,500 gallons
Typical DVE Well Spacing (Radius of Influence)	30 ft, approximately
Vapor Influent - Total VOCs Concentrations	16 ppm, maximum 1.7 ppm, average (see Figure 5.13)
Groundwater Influent - Total VOCs Concentrations	446 ppb, maximum 81 ppb, average (see Figure 5.14)
Soil VOC Mass Removal (Rate)	48.25 lb (0.17 lb/d), Total VOCs
Groundwater VOC Mass Removal (Rate)	5 lb (0.02 lb/d), Total VOCs

Unit Notes: in Hg = inches of mercury; in WC = inches of water column; scfm = standard cubic feet per minute; ft = feet; ppm = parts per million; ppb = parts per billion; lb = pounds; lb/d = pounds per day

Source: Terra Vac (1996)

Figure 2. Process Flow Diagram of DVE System (modified from Terra Vac, 1996)

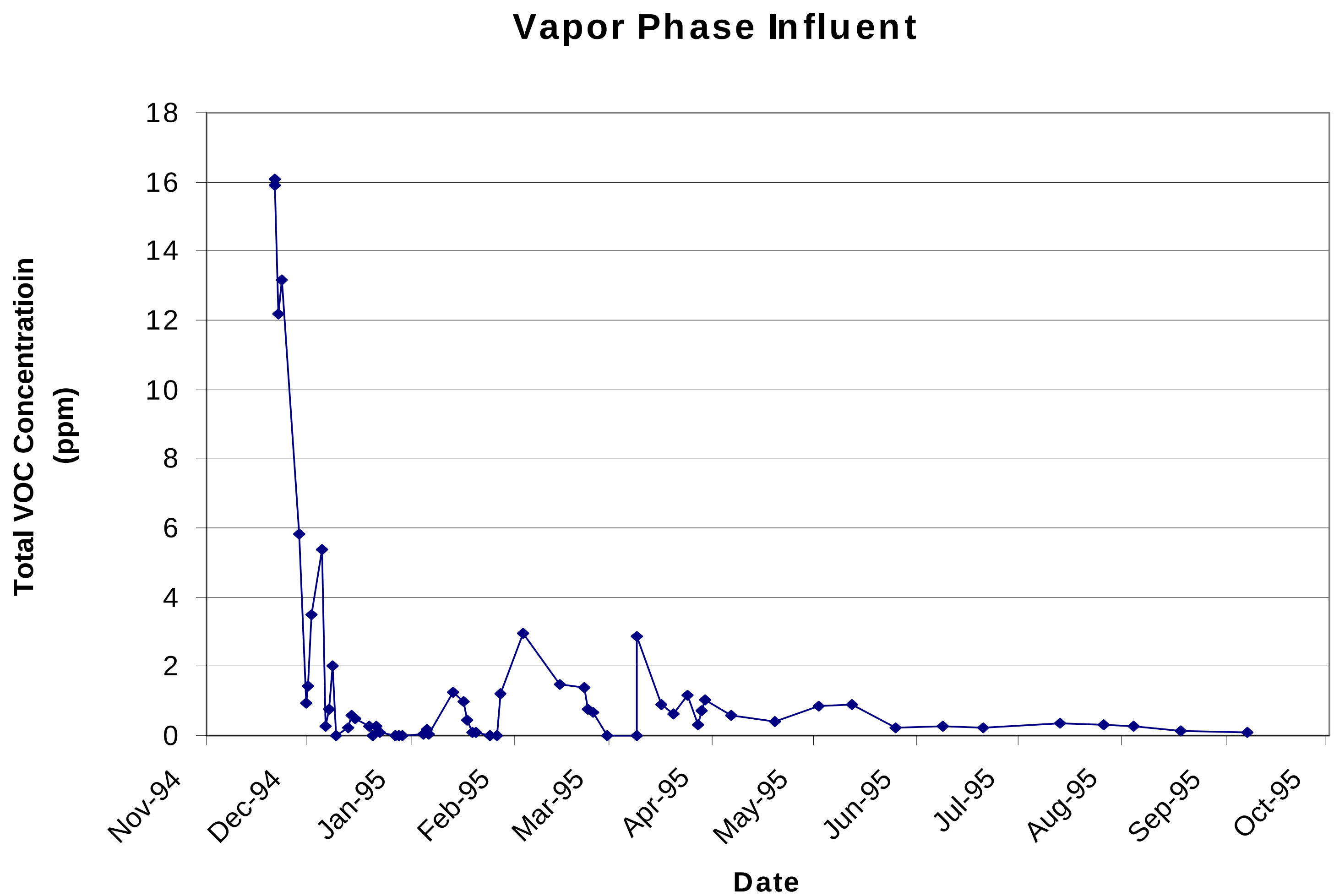


Vapor extraction flow rates averaged 500 sfcm at 5 inches of Hg vacuum (approximately 68 inches of water). Vapor extraction emissions were routinely monitored at the blower inlet to support mass removal calculations. A plot of the variation of vapor phase VOCs in the DVE system influent is provided in Figure 3. VOCs extracted in the vapor phase were at the highest concentrations (16 ppm) at the onset of DVE system operation and continued downward, over time, averaging 1.6 ppm for the project duration. One of the three DVE manifolds was shut down permanently after one month of operation due to negligible concentrations of VOCs in the vapor influent. This allowed for recovery efforts to focus on the most contaminated regions of the source area. All remedy performance verification samples collected at soil borings located throughout the site at the conclusion of the project indicated that the soil had been remediated to or below the remedial action objectives for soil (1 ppm total VOCs).

Groundwater concentrations in the influent increased significantly after approximately two months of operation. The influent concentrations then generally decreased such that by the tenth (last) month of operation they were similar to initial levels. Figure 4 illustrates this observation. The maximum total VOCs detected in the influent was 446 ppb and averaged 81 ppb for the project. The overwhelming majority of VOCs recovered were PCE and TCE. The BTEX compounds comprised only a small portion (< 5 ppb) of the VOCs recovered in the aqueous phase. Concentrations of VOCs in groundwater in the source area showed notable decreases over the period of DVE operation. Of the two wells in the source area, one showed a decrease in total VOCs concentration of over 99% and the other 64%. However, remedial action objectives for groundwater were not obtained at the conclusion of DVE system operation. Groundwater quality data collected since the termination of DVE show total VOCs concentrations ranging from 29 to 237 ppb in the source area and averaging 82 ppb in five source area wells. Long-term operation of a management of migration system (pump-and-treat) has been implemented for this area. The total volume of groundwater recovered during DVE system operation was 1,116,500 gallons.

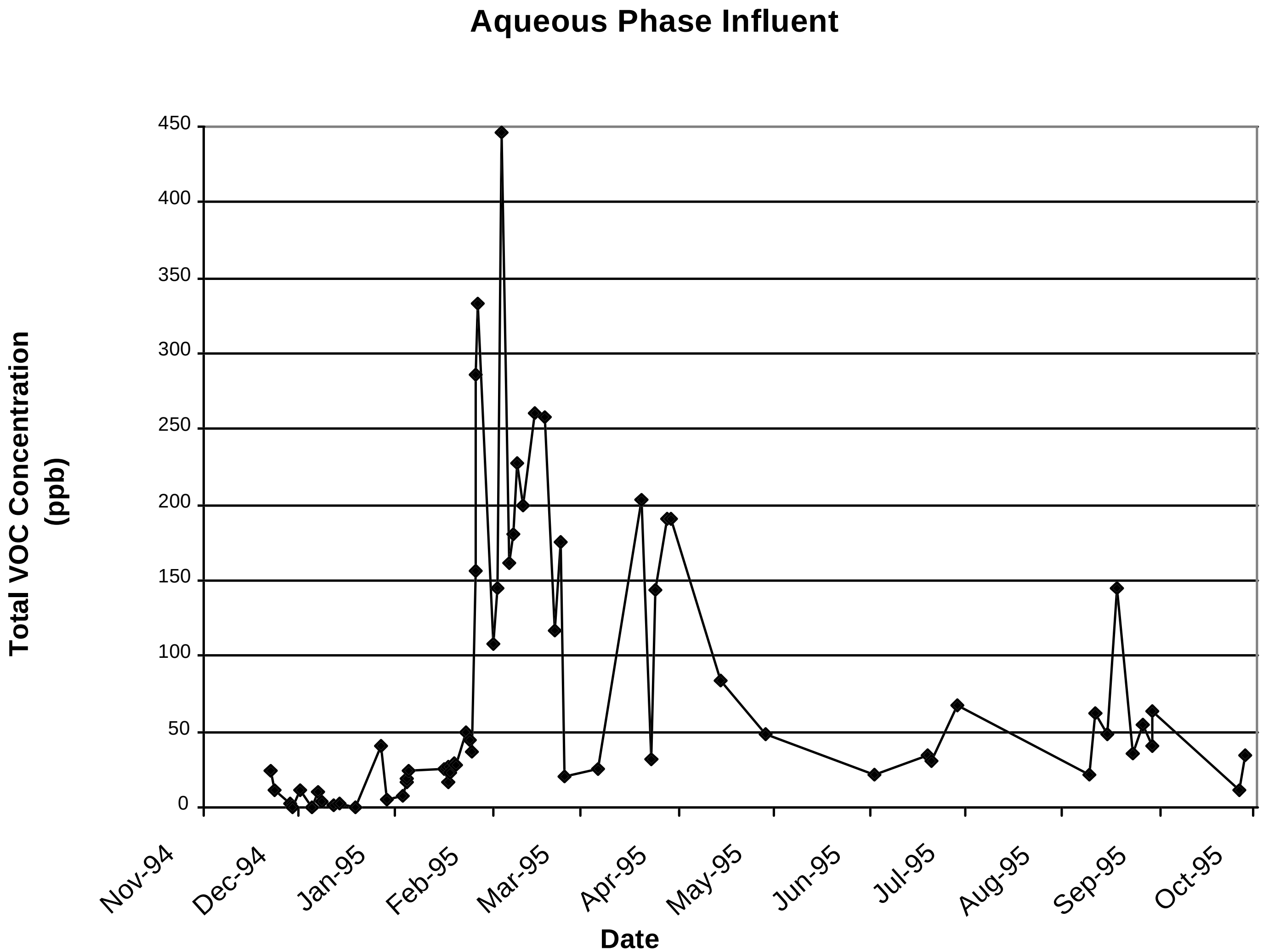
Mass removal rates were calculated based on analytical sampling and volumetric flow rates of vapor emissions and groundwater. In total, approximately 53 pounds of VOCs were removed by the DVE system. The vapor extraction portion of the system accounted for the most significant removal at approximately 48 pounds. This figure was derived based on measurements obtained at the inlet of the SVE blowers. It is likely that the actual removal is greater than 48 pounds since air-bleed valves, used to balance system vacuum, diluted the concentration of influent vapor prior to measurement at the blower inlet. A plot of VOC removal in the vapor phase over the project duration is provided in Figure 5 and is

Figure 3. Time variation of vapor phase VOCs in DVE system influent[1]



[1] Plot reproduced from data reported in Terra Vac (1996).

Figure 4. Time variation of aqueous phase VOCs in DVE system influent[2]



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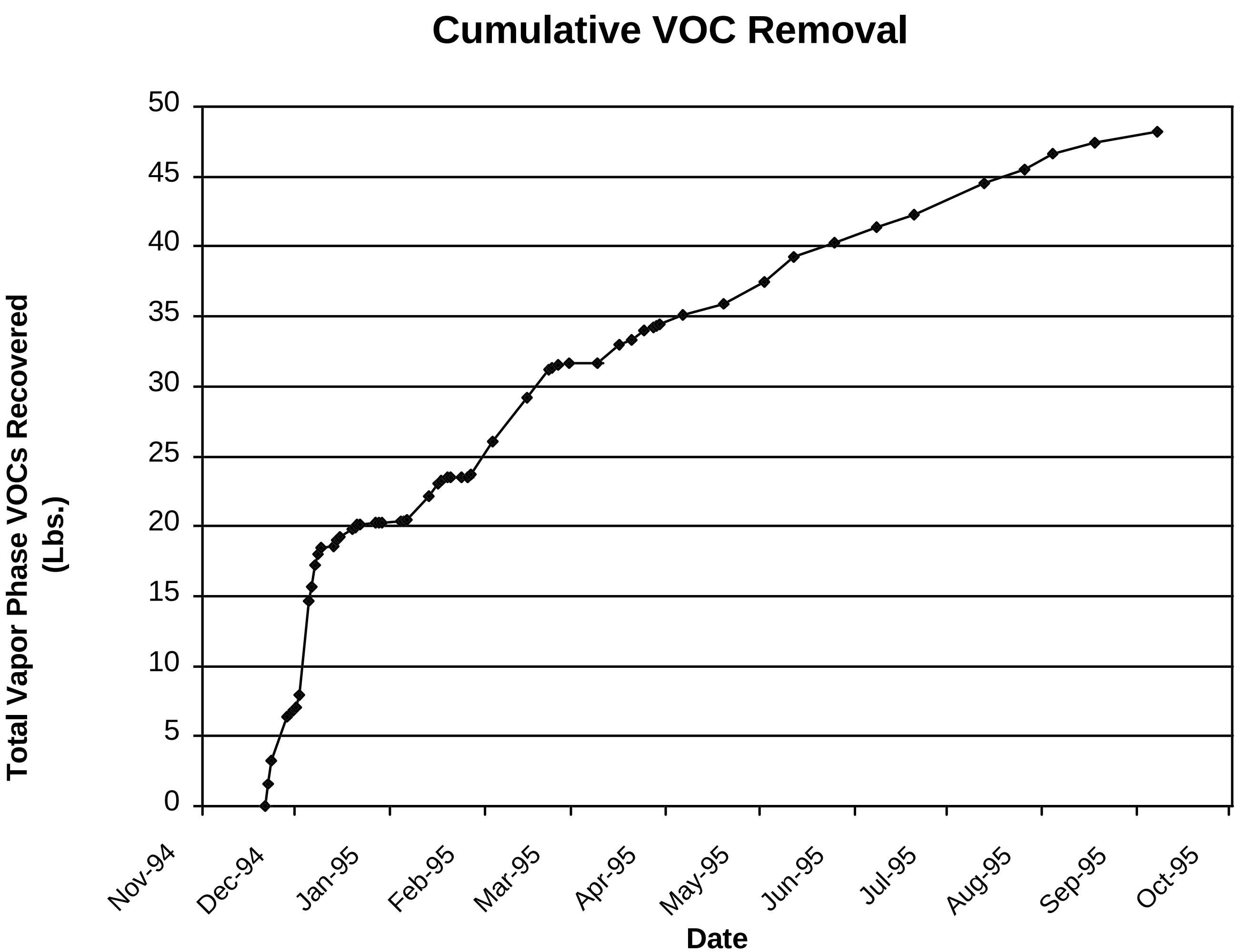
2 Plot reproduced from data reported in Terra Vac (1996).

Figure 5. Cumulative vapor phase VOC removal by DVE[3]



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3 Plot reproduced from data reported in Terra Vac (1996).

based on the blower inlet data. Vapor phase VOC removal rates were steady over the system operation and averaged approximately 0.17 pounds per day. Approximately 5 pounds of VOCs were recovered in the aqueous phase through groundwater extraction averaging 0.016 pounds per day over the project duration.

Technology Cost

The actual cost, not including permitting and oversight costs, was $170/cy ($1.5 million based on 9,000 cy treated). This figure includes an inflationary cost adjustment, granted due to significant time delays, and design changes for system winterization measures. The majority of the cost increase was realized during the period prior to completion of the sewer line, as a result of performing additional field tests to evaluate interim water discharge alternatives.

Costs for on- and off-site soil remediation alternatives were estimated prior to the remedial design phase. These estimates, based on 1986 dollars, included on-site thermal aeration at $288/cy, biological treatment at $133/cy, and off-site incineration at $2,400/cy. The original estimate for DVE in the source area was $116/cy. Project delays of two years, primarily due to the lack of availability of a groundwater discharge point (see Table 2) and regulatory permitting for off-site discharge, added to the overall cost of the DVE system.

Summary of Observations and Lessons Learned

The following conclusions and recommendations were identified based on the reported performance of the DVE system during its operational period.

- According to the RPM, at this site, soil remediation was dependent upon the ability to extract and discharge groundwater. DVE, like any groundwater extraction and treatment technology, is highly sensitive to the existence of a feasible discharge point. The project proceeded under the expectation that groundwater discharge could occur. However, an acceptable discharge point would not be made available until the sewer connection to the Derry POTW was completed. Significant project delays (two years) and subsequent increased costs were realized as a result of a lack of availability of an acceptable discharge point.

Additional observations were provided by the PRP's consultant (Terra Vac, 1996).

- The site conditions were favorable for DVE to be implemented for soil and groundwater remediation.

- DVE proved effective at remediating a significant volume (9,000 cy) of contaminated soil to below remedial goals (1 ppm) in a relatively short period of time (10 months) with overall project costs competitive with other applicable remedial technologies.

- DVE affected some mass removal of VOCs dissolved in groundwater within the source area. It is important to note that DVE was not intended to obtain remediation goals for groundwater. The extraction and treatment of groundwater was necessary to target and remediate soil contamination located in the saturated zone. A long-term migration control remedy (pump-and-treat) is currently operating to obtain groundwater remediation objectives.

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